MODAS Validation in Littoral Areas Using GRASP

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LONG-TERM GOALS

Our long-term goal is to assess the impact of temporal and spatial dynamics of oceanographic and meteorological factors on Navy sensors, systems, and operations. We will continue to improve our ability to exploit advances in remote sensing and climatology in the development of environmentally sensitive algorithms to improve ASW effectiveness in shallow-water, littoral regions. We intend to integrate a wider range of acoustic propagation and sonar performance prediction models to provide search sensor track optimization. Current work has focused on the Genetic Algorithm (GA) to optimize the search path, but we are working on a Synthetic Annealing algorithm for problems where the GA is inefficient. We continue to develop GRASP in the areas of target motion modeling, multiple constraint measures of effectiveness, and user interface issues. New goals set in the past year include bistatic acoustic simulation, true broadband acoustic prediction, and classification and tracking algorithms.

OBJECTIVES

Our FY01 objectives were to quantify the sensitivity of acoustic processes and sensor performance to spatial and temporal environmental variations in the littoral zone, both in simulations and during at-sea trials with Destroyer Squadron 24 (DESRON-24), and to downlink Modular Ocean Data Assimilation System (MODAS) fields in real time at sea to facilitate transition to actual Navy systems.

APPROACH

Our approach has been to construct an environmental grid and populate it with relevant high-resolution environmental data, including MODAS fields when appropriate. Then we define an ASW scenario and collect sensor and threat data. A prediction model (at present, CASS/GRAB for acoustic problems; GRASP also has a Magnetic Anomaly Detection predictor) then calculates signal excess for many ranges, depths, and radials at each point in the grid. GRASP then creates a Monte Carlo (MC) population of targets (based on intelligence, if available) and evaluates a given strategy against that threat distribution by calculating some Measure of Effectiveness (MOE), most often Cumulative Detection Probability (CDP). If we wish instead to optimize the search strategy, GRASP generates an initial population of random but physically realizable search strategies and uses a genetic algorithm to evolve a near-optimal strategy.

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14. ABSTRACT
Our long-term goal is to assess the impact of temporal and spatial dynamics of oceanographic and meteorological factors on Navy sensors, systems, and operations. We will continue to improve our ability to exploit advances in remote sensing and climatology in the development of environmentally sensitive algorithms to improve ASW effectiveness in shallow-water, littoral regions. We intend to integrate a wider range of acoustic propagation and sonar performance prediction models to provide search sensor track optimization. Current work has focused on the Genetic Algorithm (GA) to optimize the search path, but we are working on a Synthetic Annealing algorithm for problems where the GA is inefficient. We continue to develop GRASP in the areas of target motion modeling, multiple constraint measures of effectiveness, and user interface issues. New goals set in the past year include bistatic acoustic simulation, true broadband acoustic prediction, and classification and tracking algorithms.

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WORK COMPLETED

MODAS Accuracy. Using data from large-scale AXBT drops worldwide, we tested various strategies for reducing the predicted uncertainty in MODAS Climatology fields.

Oceanographic Impact. We analyzed how assimilation of local environmental data into MODAS fields affects mission success in littoral ASW. The method is general and gives quantitative answers for environmental sampling density.

Test and Evaluation. We took GRASP to sea with Destroyer Squadron 24 (DESRON-24) in February and May of 2001. We downloaded daily MODAS fields in real time as input to the acoustic propagation model and generated optimized search tracks from the resultant signal excess fields for a variety of DESRON-24 missions. We also timed the mission plan turnaround to provide an at-sea benchmark for later transition work.

RESULTS

MODAS Accuracy. Of those tested so far, the strategy for selecting AXBT locations that works best worldwide is to: a) weight the MODAS Climatology uncertainty by its distance from the edge of the area of interest (i.e., center-weighting), b) target the point of maximum weighted uncertainty, c) remove all points within one Rossby radius of that point, and d) repeat from step b). Figures 1 and 2 show, for several geographic areas worldwide, the summer and winter dependencies between the AXBT density (number dropped per 10,000 nm^2) and the mean RMS temperature error in the upper 300 m from ground truth. The large peak in the summer Gulf of Oman (GOO) curve is normal, as will be seen in Figure 3. That most of the curves are instead monotonically decreasing is one measure of this strategy's success.

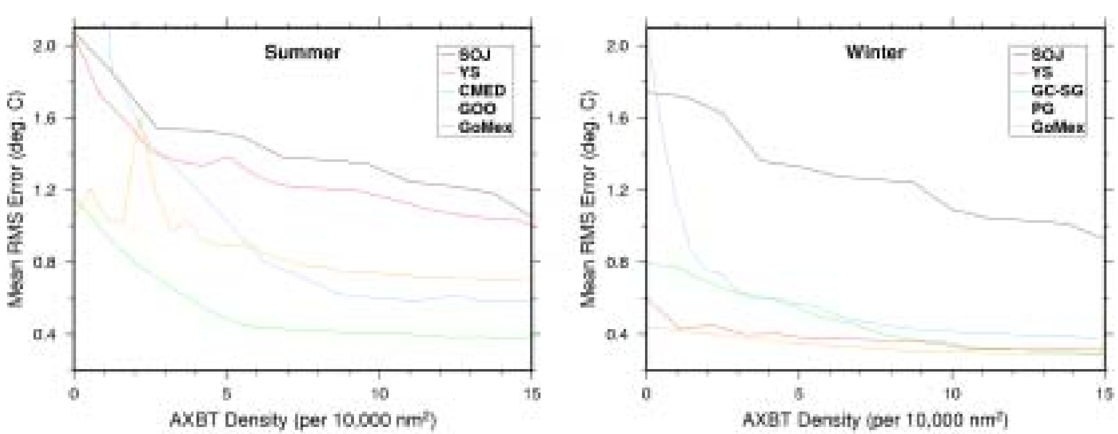

Figure 1. Summer (left) and winter (right) dependencies between mean RMS temperature error and AXBT density per 10,000 nm^2 used for the Sea of Japan (SOJ), Yellow Sea (YS), Gulf of Cadiz-Straits of Gibraltar (GC-SG), Central Mediterranean (CMED), Gulf of Oman (GOO), Persian Gulf (PG), and the Gulf of Mexico (GoMex).
[All curves start high and drop off to some stable value]

The density at which the curves become horizontal is the maximum useful AXBT density. If some RMS error could be benchmarked as marking the limit of operational value for improving estimates, then the useful limit could be reduced further. Since that is precisely the sort of question GRASP excels at answering, that is our logical next step.

Oceanographic Impact. A total of 214 AXBT temperature profiles were obtained from the Sea of Japan during 5 separate flight days. Each flight dropped 45 buoys on a uniform grid with 13.5 nm spacing; deviations were due only to buoy failures and navigational errors. Twelve acoustic environments were created by assimilating varying densities of these measurements, along with satellite sea-surface temperature data, into MODAS Climatology (CL) fields. Figure 2 shows various environmental inputs, along with effective sonar sweep widths at two depths, for this area in winter.

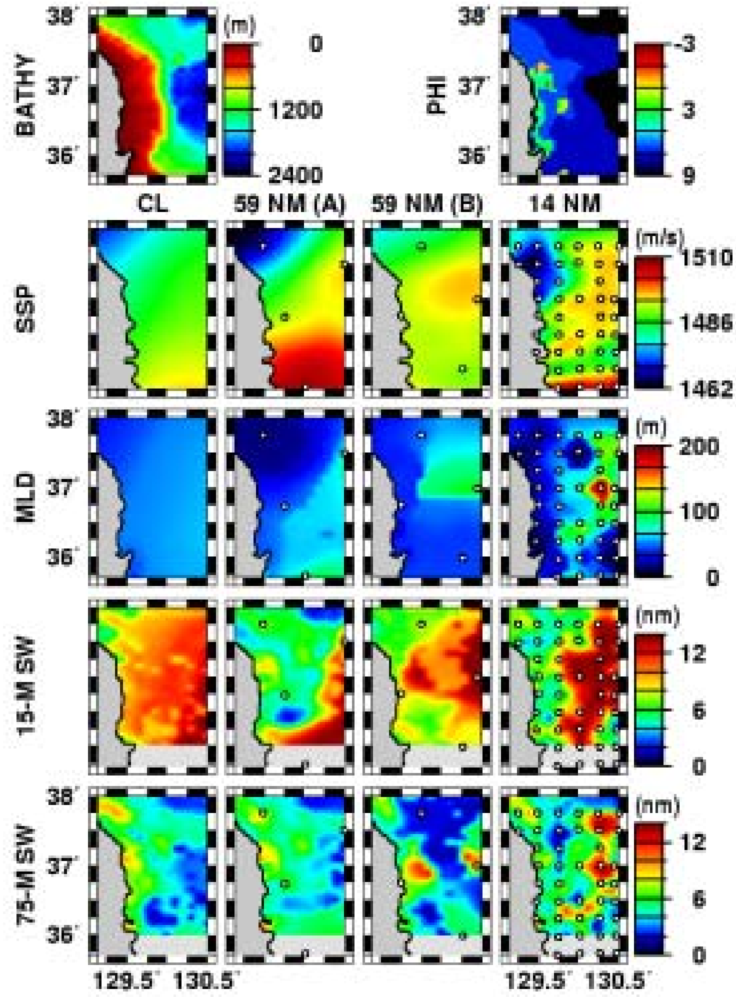

Figure 2. Environmental and acoustic conditions in winter. First row: DBDBV bathymetry (left) and surface sediment phi (right). Remaining four rows are shown for four environments, for comparison: MODAS Climatology (CL), two sparsely sampled environments (59NM(A) and 59NM(B)), and ground truth (14NM). Second row: MODAS sound speed field (SSP) at 100-m depth. Third row: MODAS mixed layer depth (MLD). The last two rows show the sweep width (a measure of detection range) for a 15-m target (fourth row, 15-M SW) and a 75-m target (fifth row, 75-M SW).

ASW search missions were simulated as 30 random (but well distributed) placements of 21 active sonobuoys in these 12 environments. To predict mission success, the evaluation module within GRASP was used to determine Cumulative Detection Probability (CDP) for the 1440 cases (2 seasons, 2 depths, 12 environments, and 30 missions). The most densely sampled environment (14NM) provided the baseline against which all other missions were judged. Figure 3 demonstrates that CDP bias (mean mission deviation from the baseline) is a strong function of environmental sampling density, and therefore can be controlled. However, CDP standard deviation is not dependent on sampling density; it is instead a function of sonobuoy placement. Since the total uncertainty in mission success (i.e., the CDP) is the sum of these two, ultra-high environmental sampling densities would not be cost-effective. On the other hand, sampling at too low a density can actually increase the CDP uncertainty compared to using only the MODAS Climatology and Sea-Surface Temperature (CLST) data. The same reasoning shows that (in this study area) no environmental sampling is needed in summer; it contributes less than 20% of the total CDP uncertainty. See reference [f] for more details.

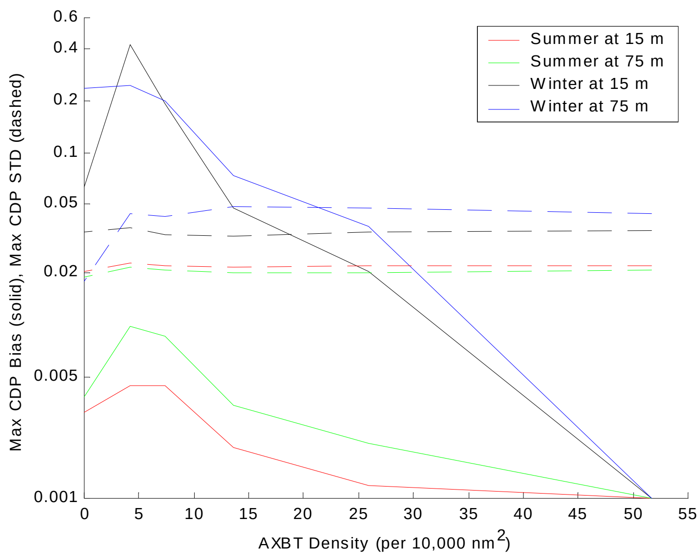

Figure 3. Maximum CDP Bias (solid lines) and STD (dashed lines) as a function of AXBT density (per 10,000 nm^2) for both seasons and target depths (15 and 75 m). An AXBT density of 0 corresponds to the CLST data set. Bias goes to 0 at an AXBT density of 51.7 because that is the baseline data set.
[All bias curves maximize at an AXBT density of 4-8. The winter bias curves cross their respective standard deviation curves (which are flat) at an AXBT density of about 20. Summer biases are far below the standard deviations.]

Tests and Evaluation. The DESRON-24 sea trials of GRASP demanded a variety of search plans. Figure 4 shows a coordinated search utilizing two platforms against a target expected to attempt a complex transit maneuver. The blue trails are a sample of the MC target tracks, all of which obey the constraints set by the expected maneuver. The red and green tracks represent the best coordinated search plan for the two assets against that MC population to maximize the CDP. Timing tests were

conducted to determine the tactical utility of GRASP under simulated “real world” prosecution. The baseline test result (4 hr) is guiding new work on calculation efficiency.

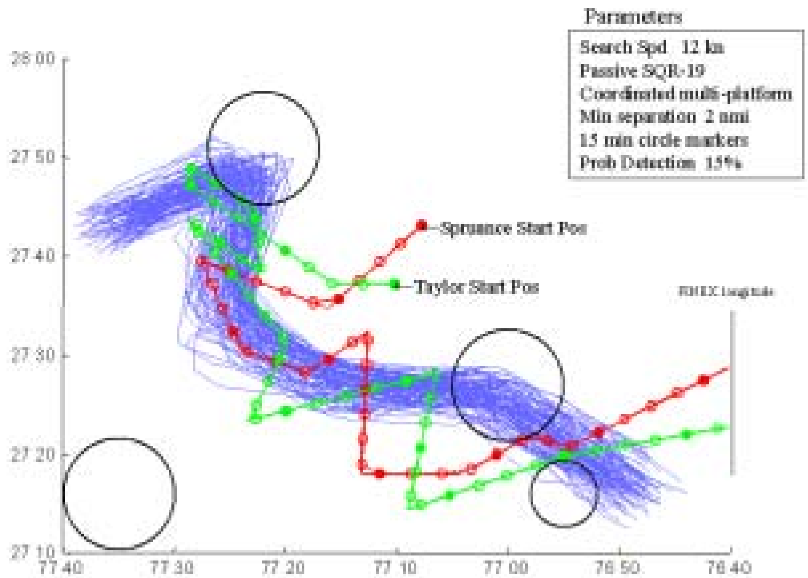

Figure 4. Near-optimal coordinated passive search plan against a complex transitor (blue) using two platforms (red and green). The braiding of the two search tracks was unexpected, but outperformed other, more “obvious” strategies.
[Transitor tracks form a river of roughly parallel potential paths. The two searcher tracks criss-cross this river like shoe lacings over much of the search plan.]

IMPACT/APPLICATIONS

Development of a tactical search optimization tool that maximizes use of environmental information will provide valuable guidance in performance assessment and mission planning for antisubmarine and mine warfare activities. These optimization tools can be used to estimate performance gains achievable by intelligent tactics for comparison with more expensive sensors and processing upgrades.

TRANSITIONS

Transition of GRASP to the Navy will begin with an installation and evaluation on the USS Roosevelt in October 2001. GRASP will interact directly with CADRT and the Mission Planner System (MPS) via the Web-Centric ASW Network (WeCAN) to provide fully automated search planning. There are many other potential spin-off transitions, including STDA, CUP, and MACE.

RELATED PROJECTS

The present effort is related to several Tactical Decision Aids, such as SIMAS, TCP, and ASPECT, and also to IMAT, whose training features can be used to aid tactical decisions.

PUBLICATIONS

[a] D. P. Kierstead and D. R. DelBalzo, “A Genetic Algorithm Approach for Planning Search Paths in Complicated Environments,” in press, Journal of Military Operations Research Society.
[b] B. Nelson, W. Avera, and D. R. DelBalzo, “[MAD],” TTCP *Conference Proceedings*, October 2000, Halifax.

[c] D. R. DelBalzo, M. D. Wagstaff, M. J. Collins, and K. P. Hemsteter, “Environmental-acoustic impact on optimum sonar search,” Proceedings of the 17th International Conference on Acoustics, September 2001, Rome.

[d] D. R. DelBalzo, M. D. Wagstaff, E. R. Rike, and K. P. Hemsteter, “Acoustic and practical constraints on optimum sonar search” 17th International Conference on Acoustics (follow-on volume), in press, Rome.

[e] D. R. DelBalzo, K. P. Hemsteter, and David P. Kierstead, “Improving ASW in littoral regions with GRASP multi-sensor search optimization,” Proceedings of the Undersea Defense Technology Conference, October 2001, Honolulu.

[f] M. J. Collins, D. R. DelBalzo, M. D. Wagstaff, Jr., and E. R. Rike, “Using TAM ocean temperature data to reduce uncertainty in predicted IEER systems performance,” Journal of Underwater Acoustics (submitted).

[g] http://www7180.nrlssc.navy.mil/homepages/GRASP/GRASP.html